Cryogenic Summary - Testing D2L104 in MAGCOOL, Part I (10/30 – 12/18/2002)

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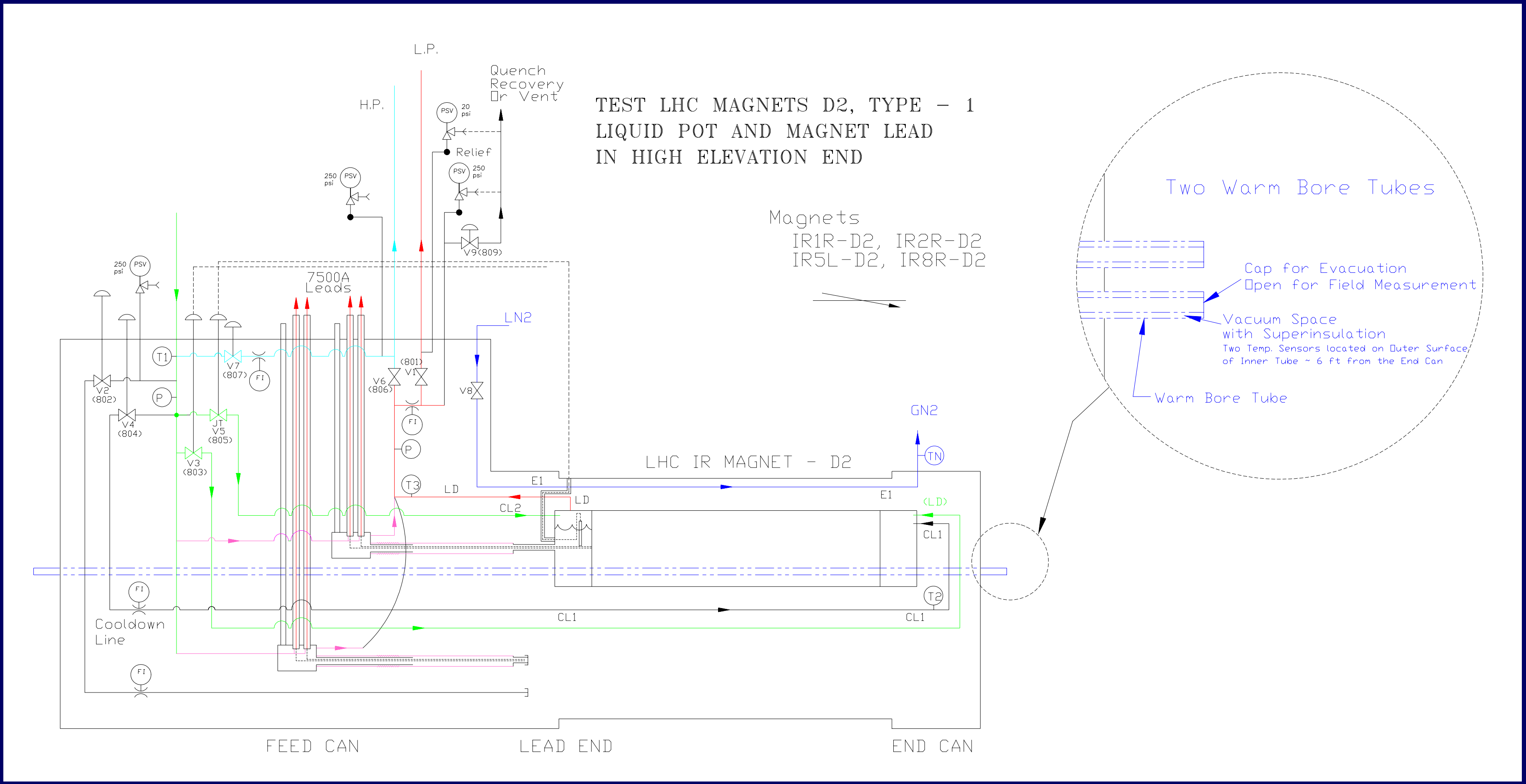
1/11/03

- General Description
- Operating Summary
- Quench Performance
- Detail Operation
- Cryogenic Test Condition
- Summary

General Description – D2L104

- 0.28 % slope (slightly less than the 0.36 % slope in LHC IR8),
- Warm bore tubes inserted and evacuated
- Information on the Warm Bore Tube and measuring device can be obtained from
    - A. Marone - andym@bnl.gov
    - G. Ganetis – ganetis1@bnl.gov
    - D. Sullivan – dans@bnl.gov

Flow diagram of D2L104 with Warm Bore Tubes – Capable of feeding liquid He from either high or low elevation ends



Operating Summary

- 1st cooldown (10/3)

  Ultem insulator on (+) lead cracked in the beginning of 5 K cooldown. Stop cooldown. Proceed warmup and replace insulator.

- 2nd cooldown (11/29)

  Test D2 in forced flow and liquid. Blockages of flow passage in all 4 leads after a drift in the weekend of 12/7. Proceed warmup to get rid of the contaminants.

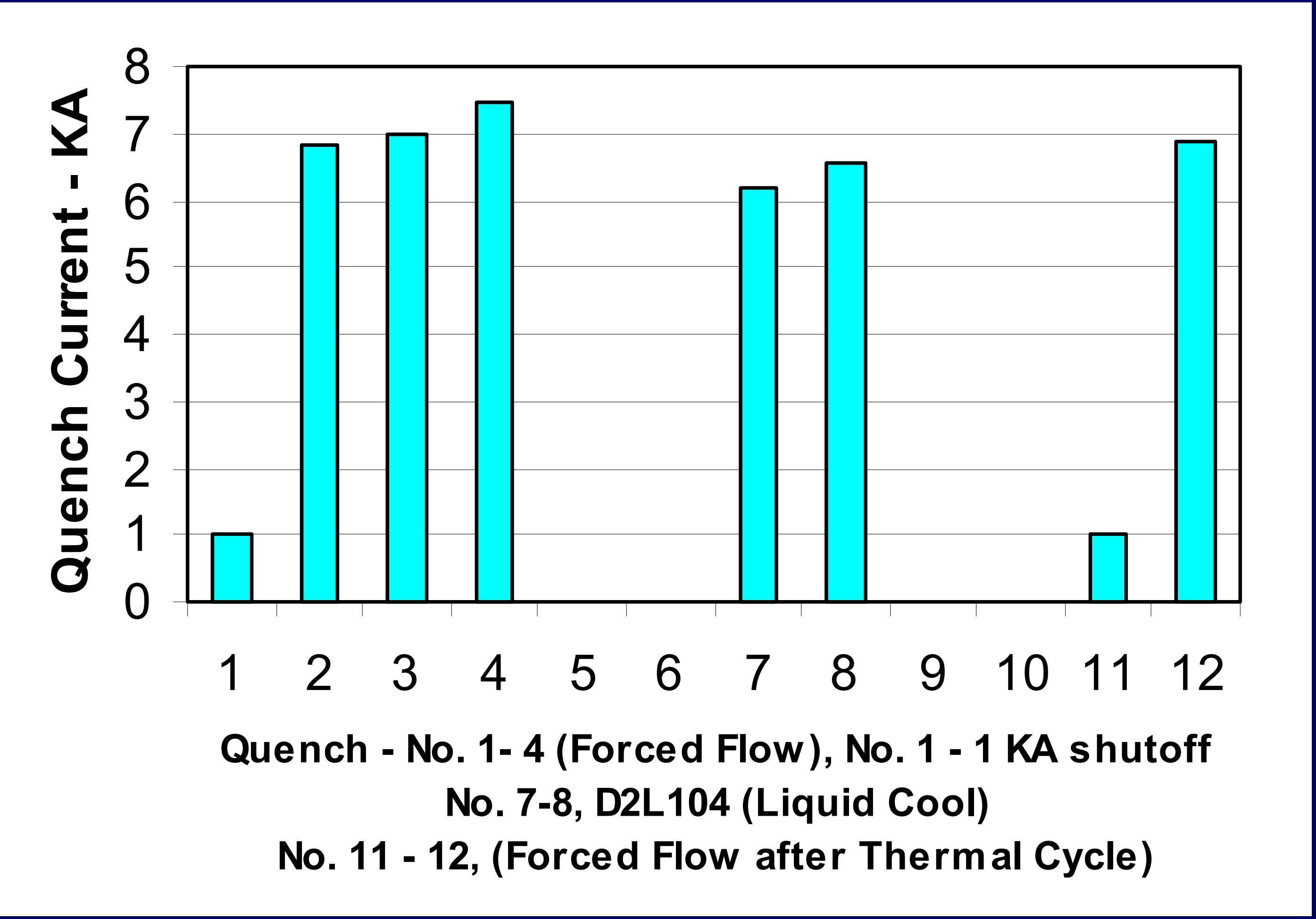
- 3rd cooldown (12/11)

  Test D2 in forced flow after the thermal cycle. Problem occurred on the transformer in B902 substation. Test was cut short due to Christmas holiday. Proceed warmup.

Quench Performance - D2L104

- 1st test group (forced flow cooling ~ 4.65 K),
  - Shut off - 1000 A (12/5)
  - 1st quench – 6827 A (12/5)
  - 2nd quench – 7001 A (12/6)
  - 3rd quench - 7467 A (12/6) (considered as 7500 A)
- 2nd test group (liquid cool ~ 4.68 K),
  - 1st quench - 6169 A (12/6)
  - 2nd quench - 6567 A (12/7)
- 3rd test group (forced flow cooling ~ 4.59 K),
  - Shut off - 1000 A (12/16)
  - 1st quench - 6890 A (12/16)

Quench Performance of D2L104 with Warm Bore Tubes Evacuated (1000 A is Shut Off)



Operation (10/30 – 12/2)

- 10/30 – 11/2 — 1st time cooldown for D2L104.
  Encountered several equipment failures.
  Took almost 4 days to reach 100 K.
  Approximately 10 minutes after 6 K cooldown began, found the Ultem insulator on (+) lead cracked.
- 11/4 – 20 — Proceed warmup and install a new insulator.
  Both warm bore tubes, lead pot window and vacuum vessel were removed and re-installed..
- 11/21 – 27 — Warm measurement
- 11/29 – 30 — Begin 2nd time 100 K Cooldown,
  Rate was slightly slower than 1st time
- 12/1 — CS5 tripped overnight, restart cooldown
- 12/2 — Takes 3 days to finish Cooldown I

Operation (12/3 – 12/6)

- 12/3 Proceed 100 to 6 K cooldown. Use one expander E19. E20 keeps on tripping and unable to run more than 10 min.
- 12/4 Reached 20 K in the morning or 100 to 20 K in 24 hours. Increase JT flow and started E20 to assist cooldown. After many trips and fix up on E20, we reached 8.5 K in ~ 7 hours. Perform high pot check.
- 12/5 1000 A shut off. 6827 A quench
- 12/6 Warm bore insulating vacuum 0.005 Torr, Vacuum inside warm bore ~ 0.170 Torr, Insulating vacuum for D2 < 10^{-6} Torr
- 12/6 7001 A, 7469A quenches – considered forced flow cooling complete.

Operation (12/6 – 12/7)

- 12/6 Switch to liquid cool in ~ 30 min. smoothly, It takes ~ 2 hours and not fully cooldown, Reach acceptable test condition for liquid mode, 83 % liquid level in high end & 89 % in low end. Difference ~ 6 % or ~ 3 cm. Agree with slope of 0.36%. Quenched at 6169 A - surprisingly low.
- 12/7 D2 stay in liquid mode overnight. Auto JT control produced oscillation of liquid level between 25 & 45 %. Manually set JT at 87% to bring liquid level. Liquid level 86% and 93% in D2. Tare flow 0.010 g/s on all 4 leads. Increase Tare flow to 0.17 and 0.32 g/s for the (+) and (-) leads. Ramp D2. Stay ~ 5 min. at 5000 A for the voltage on the (-) lead to decrease. Quenched at 6567 A.

Operation (12/7 - 14)

- 12/7 – 8 Switch to liquid production, leave D2L104 drift
- 12/9 Find blockage of flow passages in all 4 leads during 6 K cooldown, unable to eliminate blockage using local warmup or with warm helium, proceed complete magnet warmup
- 12/10 When return temperature from D2 reached 200 – 210 K, blockage in lead 1 and 2 disappeared.
- 12/11 When return temperature from D2 reached 280 K, blockage in lead 3 and 4 disappeared suggesting the blockage is from water.
- 12/11-12 Perform leak check and proceed 100 K cooldown (3^{rd} time cooldown on D2L104).
- 12/13-14 Finish 100 K cooldown in ~ 40 hours.
  Start 5 K cooldown using two expanders. Overnight, refrigerator did not switched into the last by-pass due to minor drifting on the JT setting. Takes ~ 36 hours to finish 5 K cooldown.

Operation (12/14 – 18)

- 12/14 Perform cold check at ~ 10 K.
- 12/15 Reach 4.6 K test condition – forced flow cooling. Problem on power supply. Unable to ramp.
- 12/16 Problem developed on Transformer in B902 substation. Electrical power to HEUB was off for ~ 5 minutes during diagnosis of Transformer. HEUB was shutdown manually. After temporary power is available, recool D2 to test condition. Perform 1000 A shutoff and 6890 A quench. Warm bore insulating vacuum is believed ~ 0.005 Torr, vacuum inside warm bore ~ 0.170 Torr, Insulating vacuum for D2 $< 10^{-6}$ Torr
- 12/16 Shutdown HEUB after 6890 A quench for transformer work. Leave D2 drifting.
- 12/17 Electrical returned at 9:30. D2 ~ 31 K. Insufficient time to cooldown and test before Christmas shutdown.
- 12/18 Proceed warmup.

Cryogenic Test Conditions

- Forced flow cooling

  12 atm, 4.6 K & 65 g/s, magnet temperature
  ~ 4.6 K prior to ramp

- Liquid helium cooling

  1.49 atm & ~ 4.67 K in D2L104,
  (low temperature portion of MAGCOOL is not fully cold, test is performed with JT inlet between 4.5 K and 4.2 K)

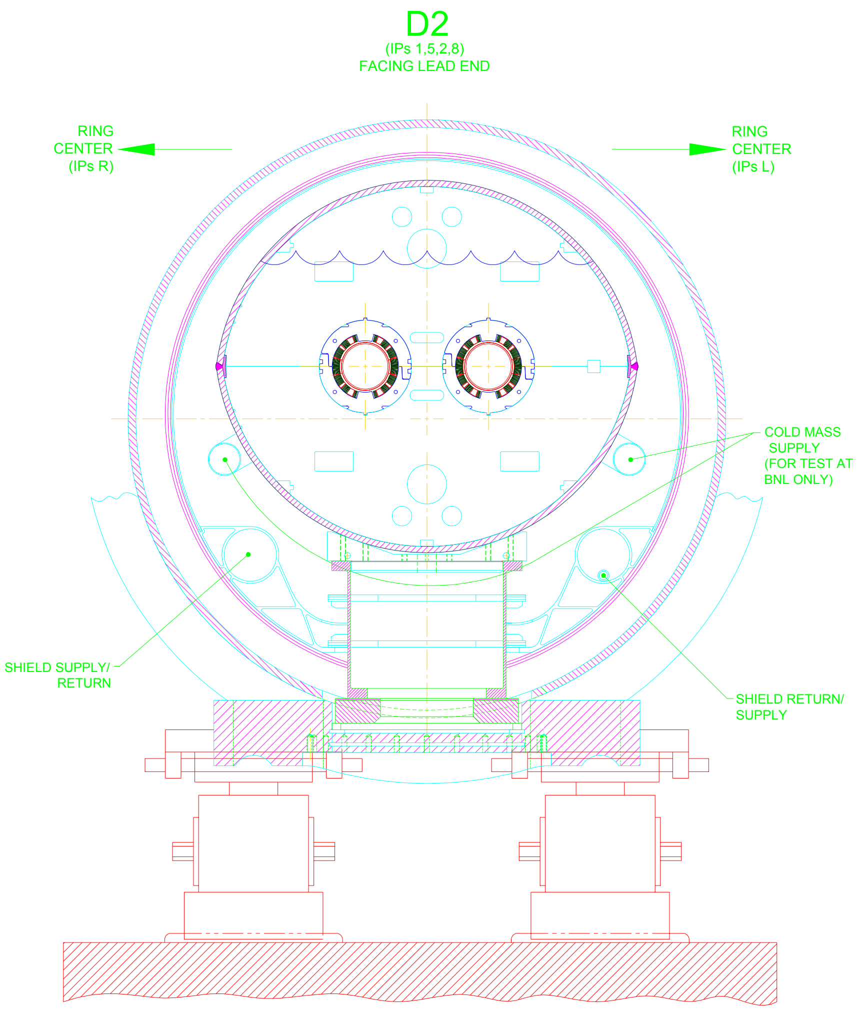
  Liquid level in end volume

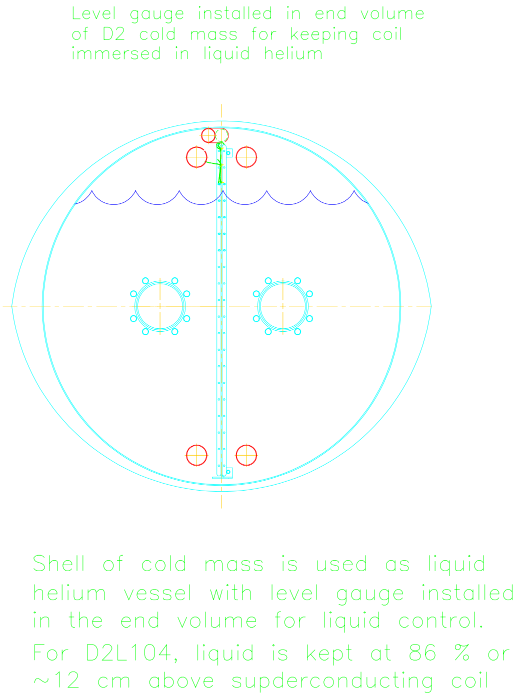
  - high elevation end: ~ 86% (12 cm above coil)
  - low elevation end: ~ 91% (15 cm above coil)

  JT Valve

  - Inlet condition: 11.8 atm & 4.5 K to 4.2 K
  - Liquid after expansion: ~ 82 % to 89 %

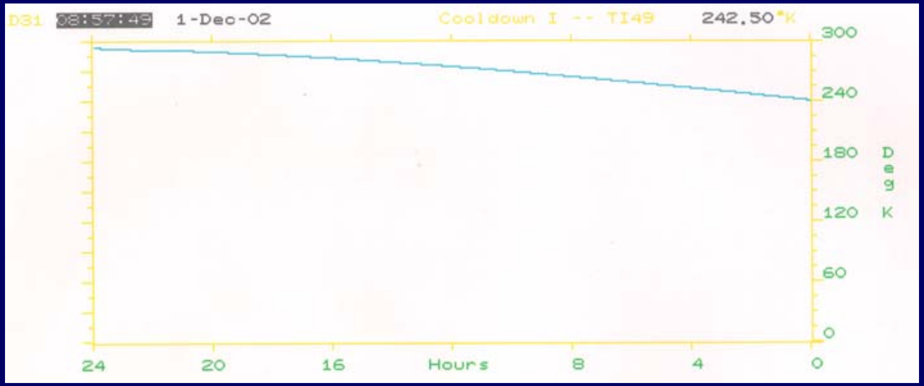
Sectional View of D2 with Liquid Level in High Elevation End ~ 86% for D2L104 (Left Figure), Level Gauge in End Volume (Right Figure)





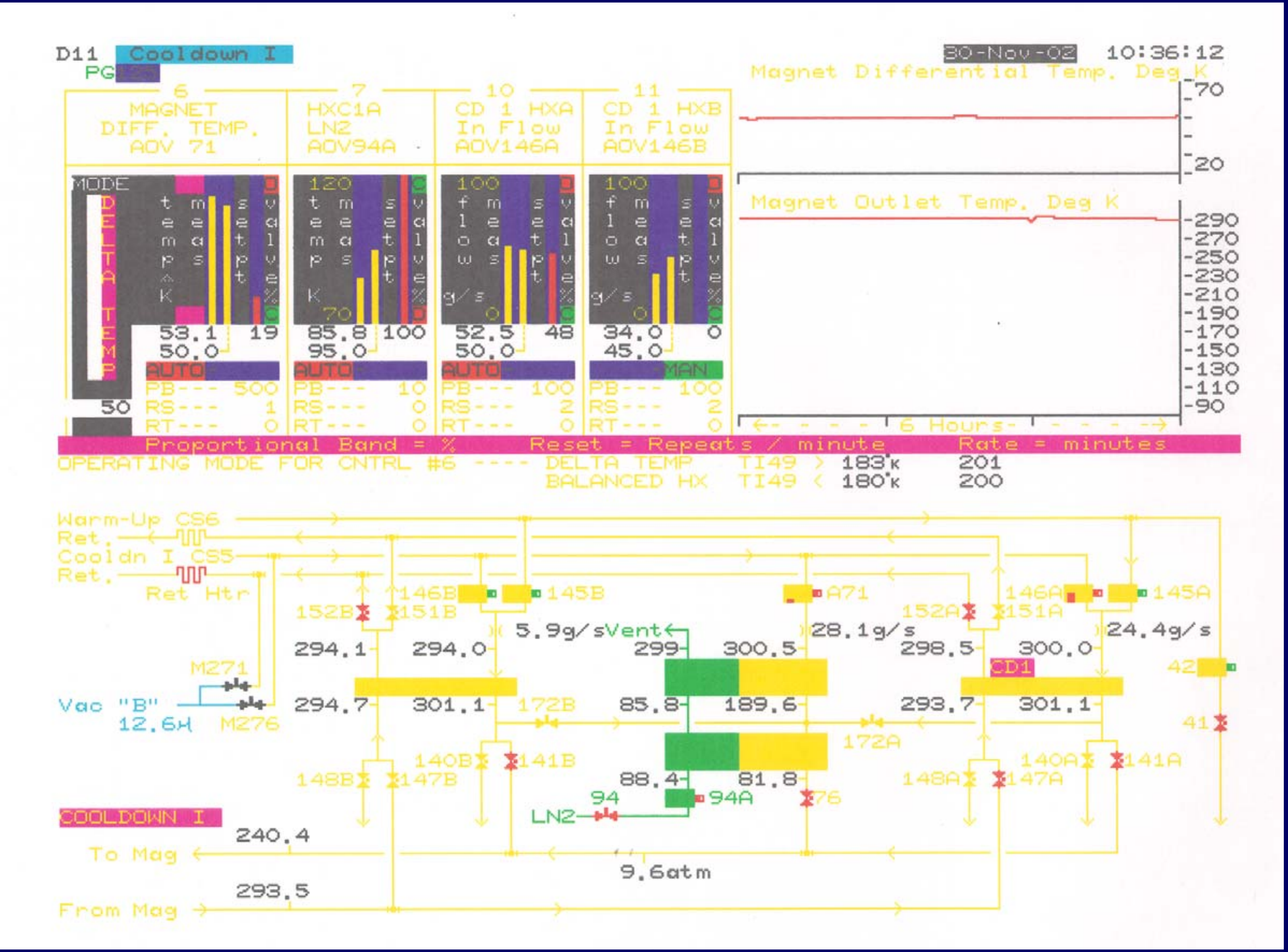
Cooldown from 300 – 100 K for D2L104

(11/30-12/3/02)

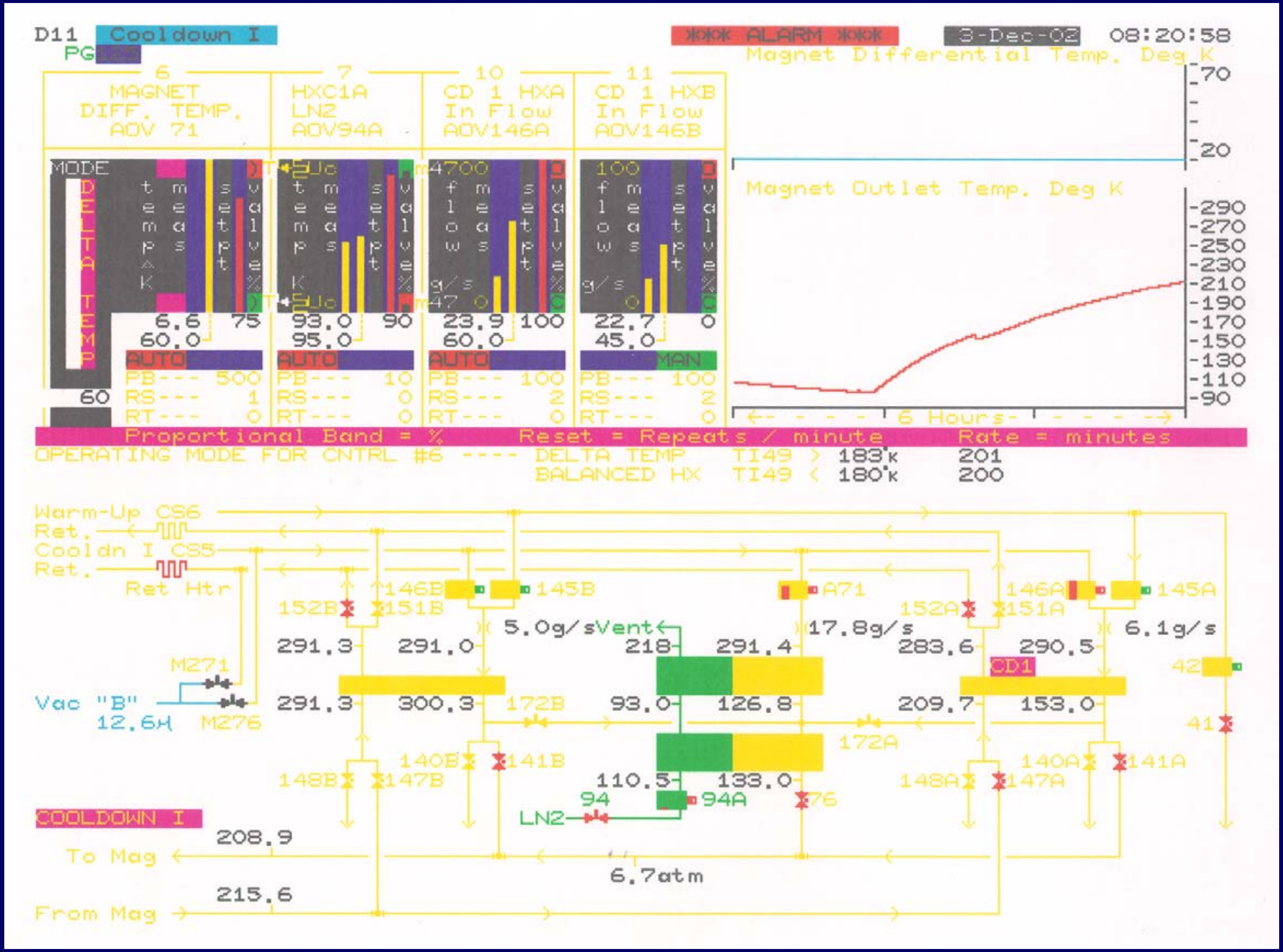


- 100 K Cooldown time ~ 3 days
- Use 50 g/s of helium flow for MAGCOOL cooldown I on 11/30, cooldown compressor tripped on 12/1, use 60 g/s on 12/2.
- Cooldown rate ~ 2.5 K/hour (11/30), ~ 4 K/hour (12/2)

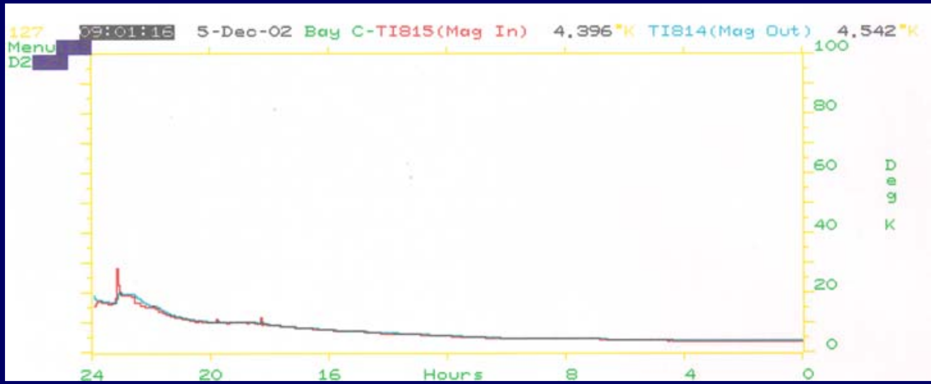
Operating Condition for 100 K Cooldown of D2L104 – 11/30/02 Day 1



Operating Condition for 100 K Cooldown of D2L104 – 12/3/02 Day 3



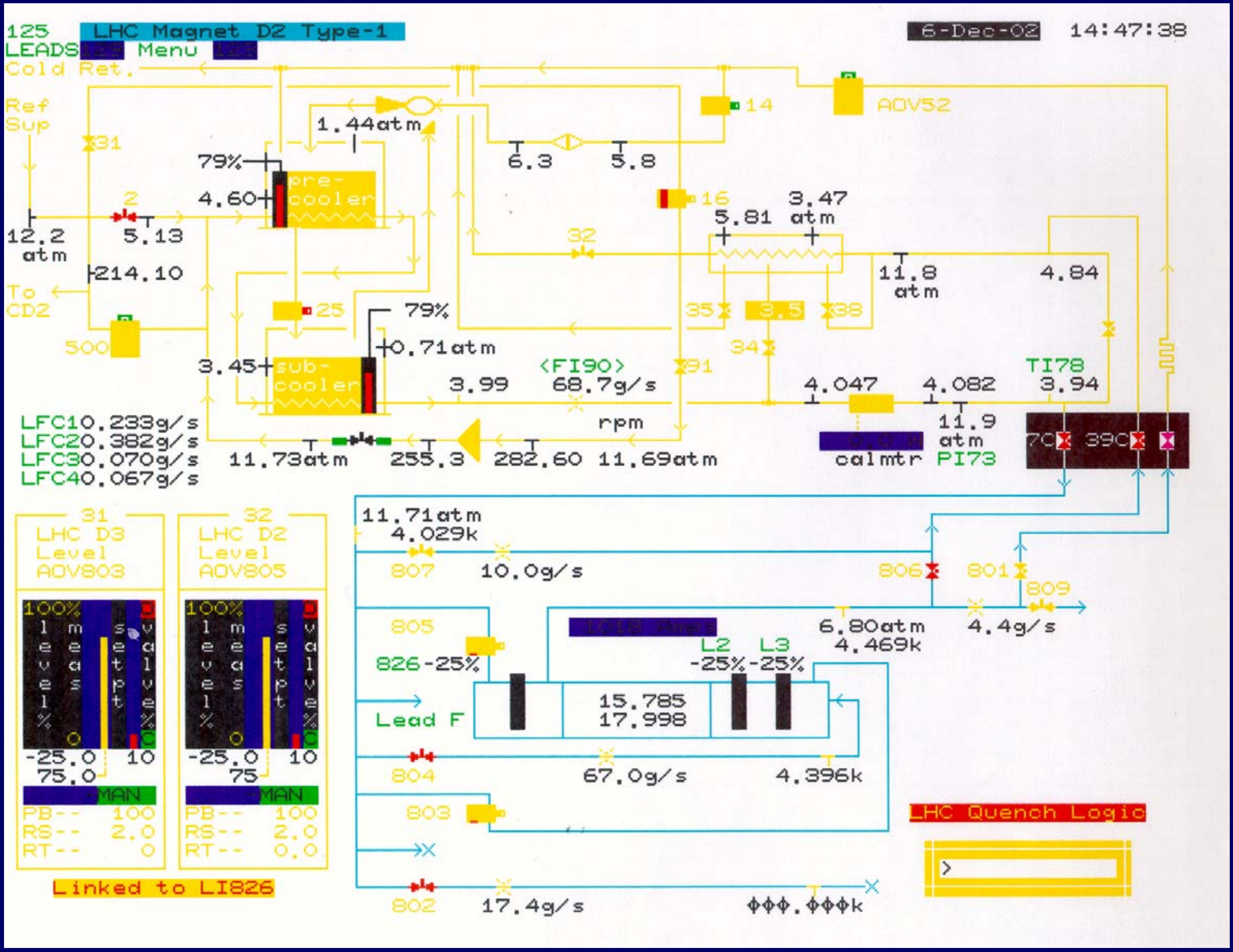
Cooldown from 100 – 6 K for D2L104
(12/4 – 5)



- •Cooldown time (100 to 20 K) is 24 hours, ~ 3.3 K/hr, using E19 only
- •Cooldown time (20 to 6 K) is ~ 8 hours, 1.8 K/hr, using E19 & E20
- •Cooldown time from 20 K to test condition is ~ 24 hours, E19 & E20
- •Temperatures at the inlet (red) and the exit (blue) of D2L104 are shown

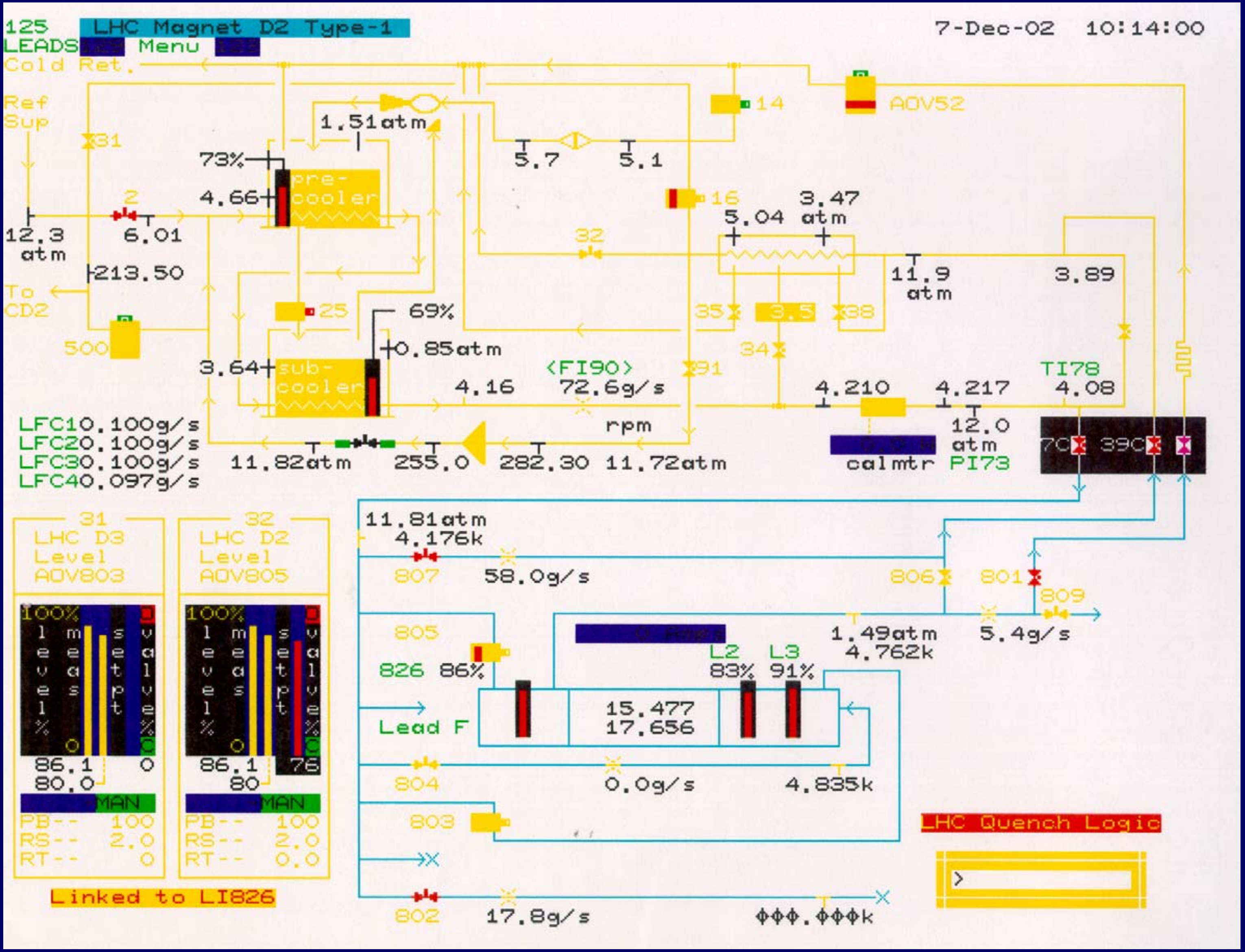
Forced Flow Cooling Condition for D2L104 at 7467 A

(Prior to ramping, return temperature is ~ 4.8 K in MAGCOOL)



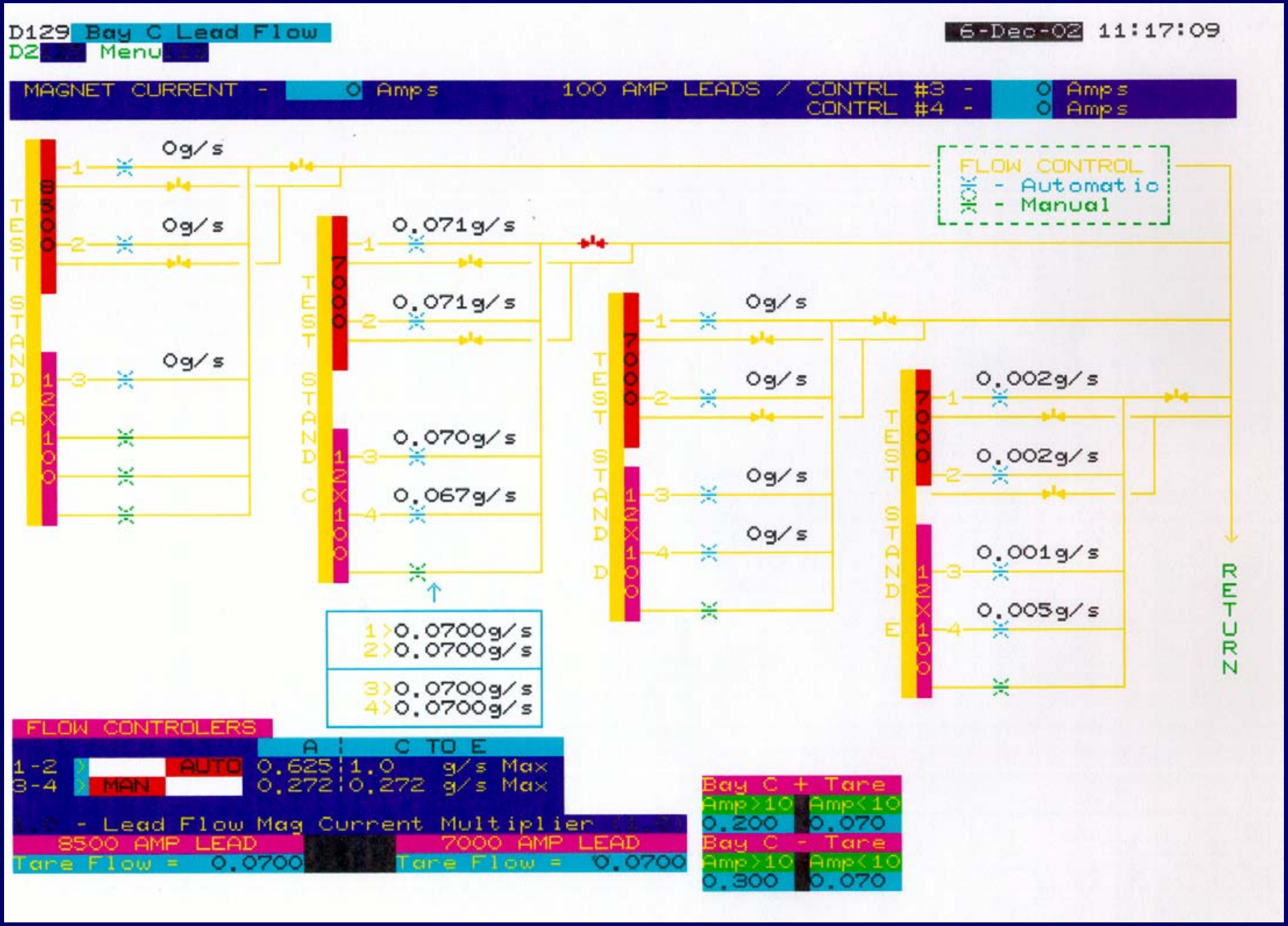
Condition for Ramping D2L104 to 6567 A – Liquid Cool

(Low temp portion of MAGCOOL was not fully cold)



Separate Flow Control for (+) and (-) Leads in Bay C

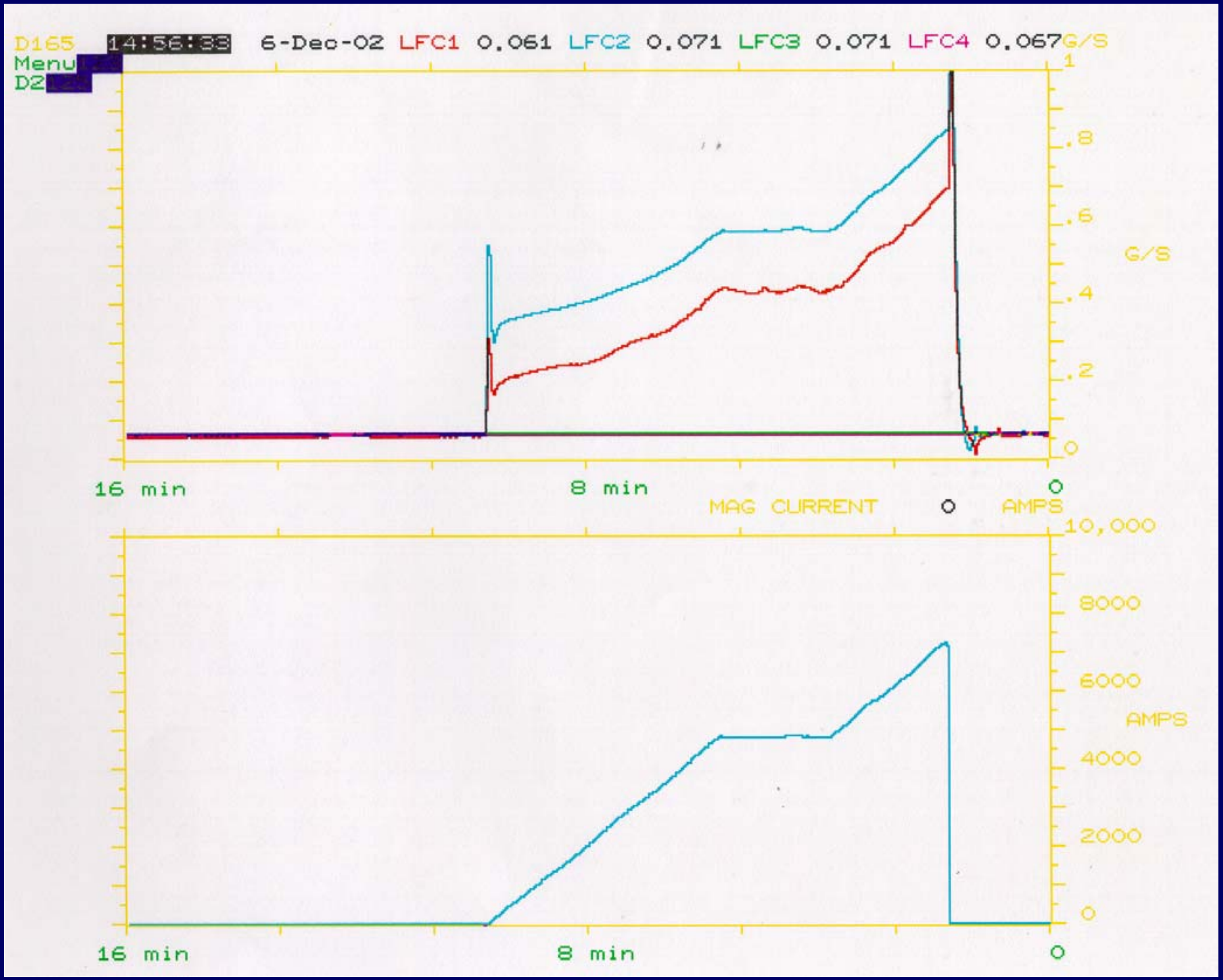
(Condition for Forced Flow ramping to 7467 A. Need to wait at 5000 A for voltage recovering in the (-) lead.)



Lead Flow and Current During Ramping of D2L104

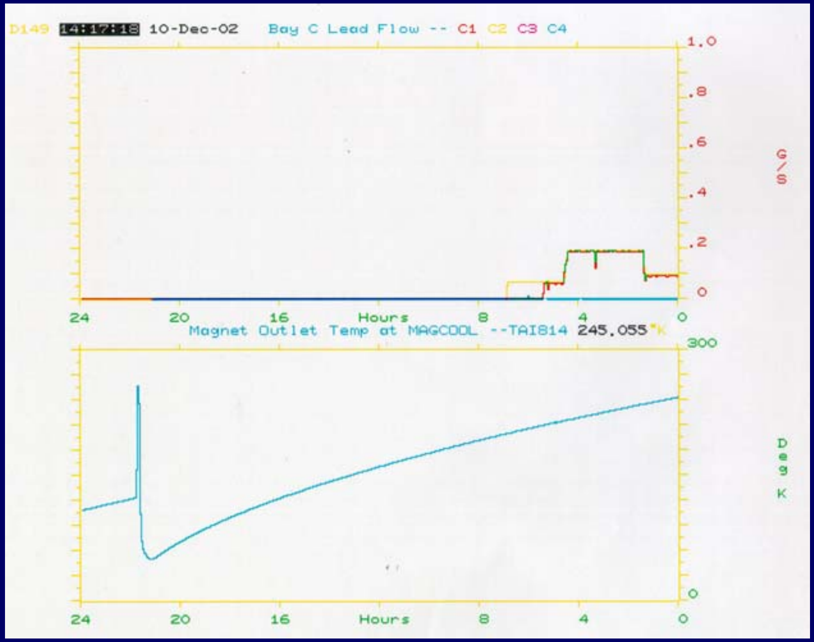
Upper Figure: Lead Flow – Blue for (-) Lead and Red for (+) Lead

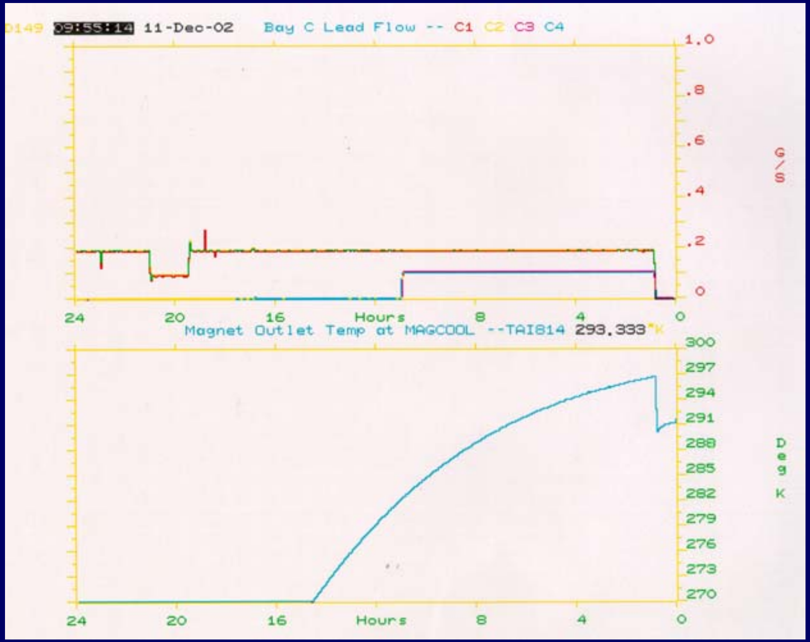
Lower Figure: Current as a Function of Time



Blockage of Current Leads as Indicated by Lead Flow (upper curve) as a Function of Time. The corresponding temperature exiting D2L104 are given in the lower curve.

Flow is able to pass through lead 1 & 2 when temperature reached ~ 210 K as shown in the left figure. As shown the right, flow is able to pass through lead 3 & 4 when temperature reached ~ 280 K.





No flow is able to pass through lead 1 and 2 until temperature reached ~ 210 K

No flow is able to pass through lead 3 and 4 until temperature reached ~ 280 K

Lead flow control – for both forced flow and liquid cool

- Main leads
  - Separate flow control for the (+) and (-) leads
  - Tare flow is set at 0.30 g/s for the (-) lead and 0.20 g/s for the (+) lead during ramp up
  - The voltage across the (-) lead is ~ 0.055 V at 7467A
- Unused leads
  - ~ 0.070 g/s for the tests

Summary

- D2L104 is the 1st D2 magnet with two warm bore tubes installed for field measurement.
- In the Part I tests, both warm bore tubes were evacuated.
- Many unexpected equipment failure and difficulties were encountered in the two months test period.
- Performance of D2L104 is not as satisfactory as that of D2L102 or D2L103.
- The 3rd quench occurred at 7467 A using forced flow cooling with the magnet at ~ 4.65 K.
- Quench currents are lower using liquid cool.
- After thermal cycle, the 1st quench is at 6890 A in forced flow.
- Lower quench currents using liquid helium cool are believed related to warm bore tubes. Unfortunately, the best way to prove is to re-do test with warm bore tubes removed.
- Test will resume in January 2003.